American-Eurasian J. Agric. & Environ. Sci., 12 (1): 91-99, 2012
ISSN 1818-6769

Zoning Wind Erosion Potential Risk in Central Iran Using Modified Numerical Taxonomy Model

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Abstract: Wind erosion is one of the most serious environmental and social-economic problems in the center of Iran. A great part of Iran including dry and ultra dry regions, due to various conditions such as insufficient soil and limited plant coverage, is very suitable for wind erosion. So far various models and methods have been presented to estimate wind erosion. Taxonomy model is one of the ranking methods used in different fields. This model was developed to classification and preparing desertification intensity map and was presented as a flexible model in Khezr Abad region with the area of 78,200ha. The aims of this research were studying and classification wind erosion potential using developed Numerical Taxonomy Model. Thematic databases, with a 1:50000 scale resolution, were integrated and elaborated in GIS based on Arc View3.2a, Universal Transfer Mercator (UTM) projection. The results showed that erosion intensity is divided into three classes, area with semi-active uptake, medium and high erosion intensity. Among the whole study area (78,200 ha) 32.2% was found to be in medium and high and 68.2% in outside wind erosion activity.

Key words: Desertification · Indicators · Wind Erosion · Numerical Taxonomy Model (MNT) · Iran

INTRODUCTION

Wind erosion is recognized as a great threat to land utilization and sustainable social and economic development. Wind erosion is also one of the most important processes in land degradation, desertification in arid and semi-arid area. It is e stimated that the degraded area caused by wind erosion amounts to 5.05 million square kilometers, accounting for 46.4% of the global degraded land [1]. After the United Nation (UN) conference on desertification in Nairobi in 1977, wind erosion as the most important factor in desertification process was given unprecedented importance [2]. Two Thirds of Iran, is located in arid and semi-arid zone, around 450,000 square kilometers of which constitute deserts. Because of poor vegetation, lack of physical features and Humidity and water shortages wind erosion occurs in desert [3]. Also, it is estimated that around 26.4 and 35.4 million hectare of land in Iran are affected by water erosion and wind erosion, respectably [4].

In the other hand, this phenomenon caused some important problems including land fertility reduction, agricultural products reduction, increasing water scarcity, soil erosion and reduction in quality and quantity of pasture resources.

Regarding population growth, increasing lands and resources utilization, presenting wind erosion risk classification map seems necessary to determine hot spots.

In this regard, to estimate wind erosion various models and methods have been presented so far such as Chepil-Wenderove model, Wodrove-Sidoy model and so on. In most of these models, the factor of soil vulnerability plays an important role. Whereas different factors such as soil texture, soil cohesion and specific gravity are effective in soil stability, Accurate quantitative estimate of this factor is impossible empirically. On the other side, these models are presented based on factors that are not native to Iran and are not compatible with Iran environmental conditions. In this situation, Iranian Research Institute of Forests and Rangelands (I.R.I.F.R)

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presented a model according to ecologic conditions of Iran and the next studies were formed based on this model regard to estimation of wind erosion [5-7].

Although IRIFR model had considered the regional conditions of Iran, but there are some Defects in factor classifications, presenting effective factors and factors scoring. Therefore, it is necessary to present a model in a particular format in which, considering local conditions to select factors, classification and scoring, so, the results can be presented by higher accuracy.

Taxonomy model is one of the ranking methods used in different fields. This method has been since 18 century. Recently, using this model has become common. According to a number of indicators, The Method classifies data into homogenous clusters can be defined and classified [8].

Taxonomy model which is one of the most important methods of stratified classification methods, was first presented by Adenson in 1757 and was for the first time used by Sneath during 1950 to 1956 to classify bacteria in microbiological issues and was later discussed by professor Hauling in 1968 as an important tool in classification of the degree of development among different nations in UNESCO. Also, this model was developed to classification and preparing desertification intensity map in Iran and finally, a natural adaptation, quantitative and flexible model was presented [9].

The aim of this research is to improve technological studies related to wind erosion and distribution of wind erosion potential in the studied area using Modify Numerical Taxonomy Model.

MATERIALS AND METHODS

Study Area: Khezr Abad region covers an area of approximately 782 square kilometers located in the center of Iran, 10 Km from Yazd city, Geographical of the study area is 31° 45´ to 32° 15´ northern latitudes and 53° 55´ to 54° 20´ eastern longitudes. The climate of this region is cold and arid based on Amberje climate classification (Fig. 1). Around 130 square kilometers (16.5%) of the region consists of sand dunes and plans,

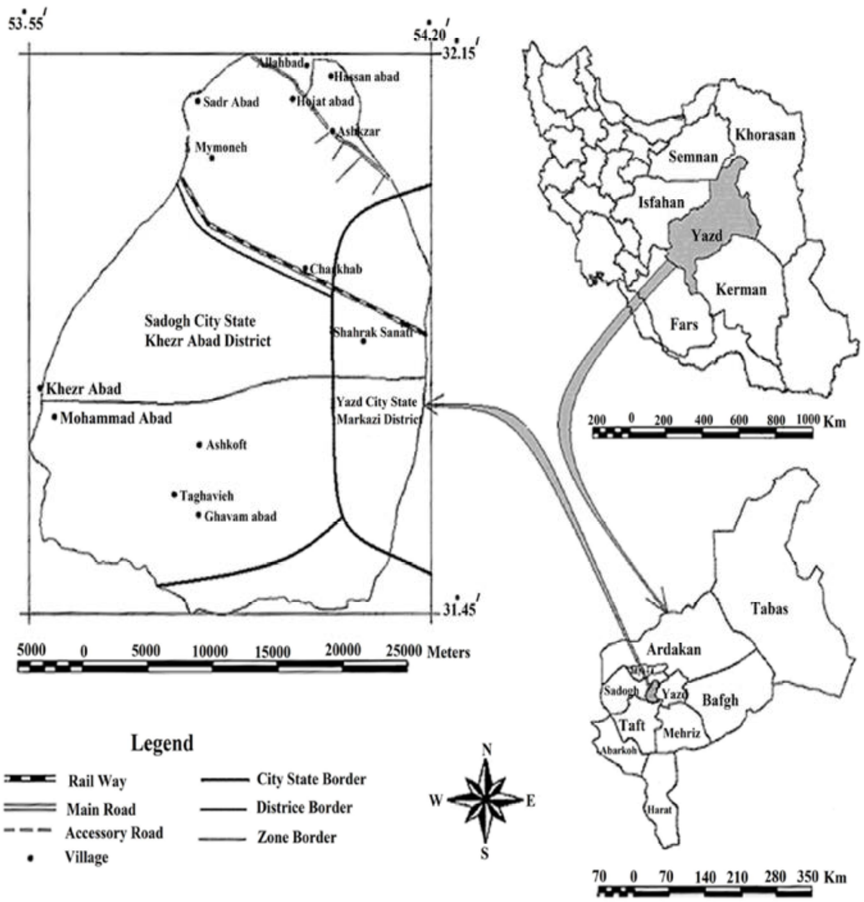

Fig. 1: Location of the study area

Table 1: Evaluation of indices in a unique scale

Criterion	Intensity ------------ Indicator	$0<WE_1$[1]$=N/n$-[2]	N/n-[2]$<WE_2=2N/n^3$-[2]	….	kN/n-[2]$<WE_n=N^2$
C_1	I_1	aI_1WE_1	aI_1WE_1	….	aI_1WE_n
	I_2	aI_2WE_1	aI_2WE_2	….	aI_2WE_n
	:	:	:	….	:
	I_m	aI_mWE_1	aI_mWE_2	….	aI_mWE_n[4]

1-wind erosion intensity

2-scale(e.g., 0-100)

3-number of matrix columns

4-represents the extent of "I" index in "WE" status of wind erosion intensity

which the large erg of Ashkzar with an area of 89 square kilometers located in the north of study area seen with various erosive facies [9]. The sandstorms region with frequency of 10 repetitions per year; dominant dust storm direction is north and northwest, brings about 120 tons of the dust per year on the city of Yazd. The combination of these characteristics indicates that wind erosion is dominant in the region and present wind erosion risk Distribution map.

Methodology: This research was carried out in Khezr Abad region during 2008 to 2010 and methodology (steps) is still underway. To classification of wind erosion potential in the study area, modify taxonomy model has been used. Classification of wind erosion potential has been presented in the following steps:

Determination of the Terrain Mapping Units and Evaluation Indices: For the evaluation of wind erosion intensity, to determine effective indices on wind erosion and present an appropriate framework for providing wind erosion zonation map, TMUs in the study area were determined and then classified. The effective indices of wind erosion and the effects of each index were determined regionally and locally. Thematic databases, with a 1:50000 scale resolution, were integrated and elaborated in a GIS based on Arc View3.2a. The Remote Sensing (RS) technique was also used as a main tool for obtaining data, analysising them and determining accurate results.

The Evaluation of Indices in a Unique Scale (N): To delete various scales for assessment, measure indices and quantify qualitative indices, the effective indices were evaluated on the same scale according to wind erosion intensity. In the primary taxonomy model, normalization method was used for non-scaling and adjustment of the indices (Table 1).

The status map of regions under influence on wind erosion was presented based on the studies performed on the wind erosion facies, using aerial photos, satellite photos and field studies. Then by pair comparison of this map with the zonation maps of effective indicators on wind erosion such as plant coverage types, soil, etc., the indicators were divided into different levels (regardsing to degree of influence on wind erosion process) (Table 5).

Determination of Each Index Value in Every TMUs: The value of each index impression on wind erosion process was evaluated by forming "TMUs and effective indices" matrix (Table 2). This process can be done individually by the experts, using the experiments and scope studies (individual taxonomy). In addition, this can be prepared by using Delphi method, forming questionnaires and asking experts who are familiar with the study area to express their opinion about each wind erosion index according to considered scale (N). The geometric mean was calculated (Eq.1) (assuming that the opinion of all people are the same) and it was combined with experts matrix and resulting to a group matrix (group taxonomy).

$$\overline{TMU,I}=\left(\mu_{k=1}^{n} TMU_m I_n^k\right)^{\frac{1}{N}} \tag{1}$$

In this matrix, TMU_mI_n states the effect of "I" index quantitatively and it is evaluated on the basis of scope, library studies and considered scale (N). In this stage and in the end of matrix formation the smallest number in each column was considered as a negative ideal number (NI), used in the following calculations. In the primary taxonomy model NI was called positive ideal number (PI). In the modified and developed model less value of TMU_mI_n (Score of each wind erosion index in TMUs) represents less wind erosion condition of the index. Therefore the least index is called Negative Ideal Number (NI_j) in the matrix.

Table 2: Matrix of terrain mapping units and effective indices

I_i[3] ------------ ▾$TMUi$[2]	I_1	I_2	….	I_n
TMU_1	TMU_1I_1	TMU_1I_2	….	TMU_1I_n
TMU_2	TMU_2I_1	TMU_2I_2	….	TMU_2I_n
:	:	:	:	:
TMU_m	TMU_mI_1	TMU_mI_2	….	TMU_mI_n[1]
NI_j[4]	NI_1	NI_2	….	NI_n

1-represents the wind erosion intensity of indices in Terrain Mapping Units

2-Terrain Mapping Units

3-indices

4-Negative Index

Table 3: Wind erosion intensity matrix of the indices and terrain mapping units

TMU_i[1]▾	$(TMU_mI_1\text{-}NI_1)^2$	$(TMU_mI_2\text{-}NI_2)^2$	…	$(TMU_mI_n\text{-}NI_n)^2$	WEM[3]	WEI[4]
TMU_1	a_1	b_1	…	y_1	WEM_1	WEI_1
TMU_2	a_2	b_2	…	Y_2	WEM_2	WEI_2
:	:	:	…	:	:	:
TMU_m	a_m	b_m	…	Y_m	$\frac{WEM_m}{\overline{WEM}}$[5]	WEI_m
NI_j[2]	NI_1	NI_2	…	NI_n	δWEM[6]	

1-Terrain Mapping Units

2-Negative Index

3-Wind erosion Measure

4-Wind erosion Intensity

5-The mean of the wind erosion Measure

6-Standard deviation of the wind erosion Measure

Formation of Wind Erosion Intensity (WEI) matrix and Assessment of Wind Erosion Measure (WEM) in the TMUs: Regarding primary evaluation matrix of terrain mapping units and effective indices (Table 2), the distance square of Wind Erosion intensity of each index, in every Terrain Mapping Units (TMU_mI_n) were calculated from negative ideal number (NI_n) of the same index (Table 3), the small distance of each index from NI_n, represents low wind erosion effects of that index on the terrain mapping unit (TMU_m) and vice versa.

The summation of total deviation squares from NI_n were calculated (by Eq.2) in each TMU_s. It is expressed as WEM of the TMU_s.

$$WEM = \sqrt{\sum_{j=1_{i=1}}^{n^m} \left(TMUiIj - NIj\right)^2} \quad (2)$$

Where:

WEM: wind erosion measure of each TMUs.

$TMUiIj$: Value of i[th] index of the j[th] TMUs.

NI_j: Ideal negative number or the smallest number in each column of data matrix

Calculating Upper Limit of Wind Erosion: In order to determine wind erosion intensity of TMUs and provide wind erosion distribution map, upper limit of wind erosion (WE_{max}) was calculated in all the TMUs (Eq. 3).

$$WE_{max} = \overline{WEM} + 2\delta WEM \quad (3)$$

Where:

WE_{max}: the high level of wind erosion of the entire TMUs.

$\overline{WEM}$ The mean of the wind erosion Measure

δWEM Standard deviation of the wind erosion Measure

Determination of Wind Erosion Intensity in the TMUs: At last, wind erosion intensity of the TMUs is calculated by (Eq.4).

$$WEI = \frac{WEM}{WE_{max}} \quad (4)$$

Where:

WEI = The intensity of wind erosion of each TMUs

WE_{max}: The high level of wind erosion of the entire TMUs.

WEM = Wind erosion measure of each TMUs.

Table 4: The classification of wind erosion risk based on wind erosion intensity viewpoint

Wind erosion risk	Wind Erosion Intensity (WEI)	class
low	0-0.25	I
moderate	0.26-0.50	II
intense	0.51-0.75	III
very intense	0.76-1	IV

According to this method, wind erosion intensity in the TMUs is always between zero and one (0=WEI=1), therefore when WEI is near to zero (0), it is concluded that wind erosion intensity of the TMUs is lower and vice versa; if the WEI is near to one it represents a high class of wind erosion intensity in the TMUs.

Classification of the TMUs from Wind Erosion Viewpoint: According to the results of wind erosion intensity in each TMUs, the Table of classification of units from wind erosion viewpoint was provided (Table 4).

Provision of Wind Erosion Intensity Distribution Map on the Base of TMUs Map: According to Table 4 and with due attention to wind erosion intensity, every TMUs was classified in one of the four classes of wind erosion intensity, low, modium, high and very high. Then the TMUs that had the same wind erosion classes were combined. Also, the final zonation map of wind erosion intensity was provided by combined TMUs.

RESULTS

The Results of this Study Are Presented as Follows

Determining the TMUs and Evaluation Indices: In order to provide wind erosion map with an appropriate framework, TMUs in the studied area were separated. The geomorphologic facieses were considered as TMUs and were identified through field operations using topographic maps (1:25000), aerial photographs (1:55000) and Land sat satellite images (ETM$^+$ 2002 with a color composite of 4-3-2 for the evaluation of plant cover and 5-4-3 for evaluation of geology). Morphology and TMUs maps were prepared by integrating hypsometric, gradient and geological maps [10]. Based on the morphological, topographical and lithological studies, 12 TMUs were identified in the study area (Fig. 2). Then, based on the amount of influence of variables in the erosion process, six variables were selected as the main effective variables on wind erosion process in the studied area. The selected variables were altitude, geomorphology, rock sensitivity to wind erosion, soil type, vegetation cover and land use. Because of the limited area of Khezr Abad region, the range of fluctuation of some variables such as wind speed and precipitation was negligible. Therefore, the mentioned variables were not considered in calculations.

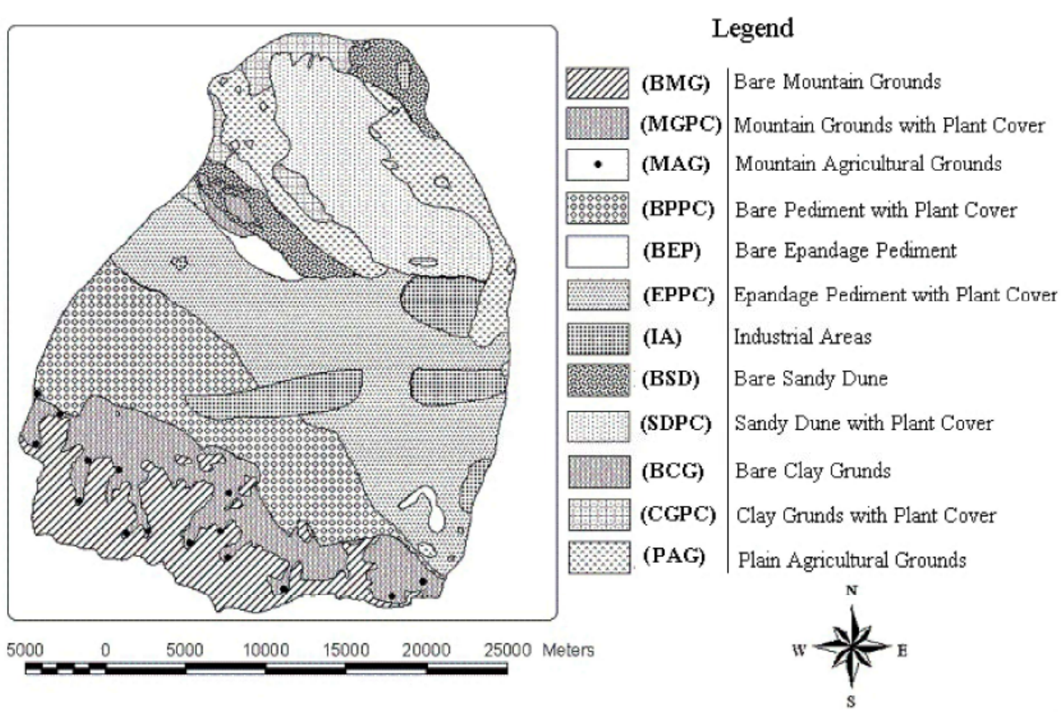

Fig. 2: Plans terrain mapping units, Khezr Abad area

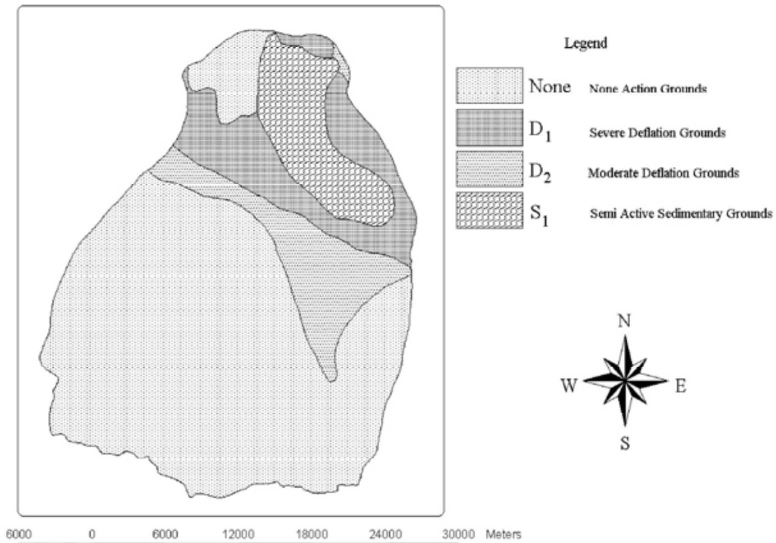

Fig. 3: Dispersion of activity of wind erosion based on erosion facies dispersion in Khezr Abad region

Table 5: scoring the indices on a unique scale

	Wind Erosion Intensity			
	Low (1-3)	Medium (3.1-5)	High (5.1-7)	Very High (7.1-9)
Elevation	1400<	1300-1400	1200-1300	1200>
Geomorphology	mountainous and highland region and bar pediment, with little soil coverage and stone out crop and gully erosion	grounds with big and average granular deposits like alluvial fan and oued beds with average ups and downs	Sand dune, sheets, farmlands of Epandage Pediment and relatively smooth	Smooth clay lands, young alluvium deposits with erosion traces such as yardang
Petrology	Limestone and esite, Dike, green shale, sandstone, Trachyte, dolomite, Silt	new Alluvium	Sand Dune	traditional terrace
Soil	[1](M) , [2] (BP)	-	[3] (EP_1)	[4] (EP_2) and [5](SD)
Plant coverage	[6] (A.Sa) , [7](C.La) , [8](A.Fo)	[9](A.Sc) , [10](Hal/B.L)	[11](Hal/S.D)	[12] (A.Co)
Land using	B(M and H) (PL)	[15](BL) , [16](I) , [17](B(S.D))	[18](A(I)) , [19](A(I),I)	[20](P(S.D)) [21](PL,A(I))

[1]-Mountain Soils(M)
[2]-Bar Pediment Soils(BP)
[3]-Epandage Pediment Soils with Low Slope (EP_1)
[4]-Epandage Pediment Soils with Very Low Slope (EP_2)
[5]-Sandy Dune (SD)
[6]-Artemisia-Salsola
[7]-Cornulaca-Launaea
[8]-Artemisia-Fortuynia
[9]-Artemisia-Scariola
[10]-Bar Land Cultivated with Halexylon
[11]-Sand Dune Cultivated with Halexylon
[12]-Artemisia-Cousinia
[13]-Bar Mountain and Hill Grounds
[14]-Sesonal Grassland
[15]-Bar Land
[16]-Industrial Zone
[17]-Bar Sandy Dune
[18]-Agricaltural Irrigation Grounds
[19]-Industrial and Agricaltural Grounds
[20]-Sandy Dune with Plant Cover
[21]-Agricaltural Irrigation and Grassland Grounds

The Evaluation of Variables in a Unique Scale: Based on the studies performed on the wind erosion facies in the study area (National Desertification Center, 2006), using aerial photos 1/40000, ETM satellite photos and field studies, the geographical status of the region under influence was presented by a map in 1/50000 scale (Fig. 3). This layer was used to analysis effective variables and to weight them.

Figure 3 shows the function of wind erosion in north, northeast and northwest of the studied area. In this situation, areas affected by erosion intensity is divided into three regions: semi-active sedimentary grounds (S_1) with area of 8050 ha (10.5 percent of the Khezr Abad region), moderate deflation grounds (D_2), 7820 ha (10 percent of the Khezr Abad) and sever deflation grounds (D_1) with 9310 ha (11.9 percent of the Khezr Abad) and

Table 6: Value of each index in each TMUs

TMUs	Index(I_j) Elevation	Geomorphology	Kind of stone	Soil	Plant Covering	Land use
(BMG)[1]	1	1	1	1	4	2
(MGPC)[2]	2	1	5	2	2	3
(BPPC)[3]	4	2	8	3	6	4
(BEP)[4]	7	8	9	7	3	3
(EPPC)[5]	6	6	9	6	8	4
(PAG)[6]	8	7	9	8	5	6
(CGPC)[7]	8	9	9	8	6	8
(BCG)[8]	8	9	9	9	4	8
(BSD)[9]	9	8	7	9	2	4
(SDPC)[10]	8	8	7	9	7	9
(IA)[11]	6	6	5	6	7	5
(MAG)[12]	2	1	3	2	2	5
NI_n [13]	1	1	1	1	2	2

[1]Bare Mountain Grounds (BMG), [2]Mountain Grounds with Plant Cover (MGPC), [3]Bare Pediment with Plant Cover (BPPC), [4]Bare Epandage Pediment (BEP), [5]Epandage Pediment with Plant Cover (EPPC), [6]Plain Agricultural Grounds (PAG), [7]Clay Grounds with Plant Cover (CGPC), [8] Bare Clay Grounds (BCG), [9]Bare Sandy Dune (BSD), [10]Sandy Dune with Plant Cover (SDPC), [11]Industrial Areas (IA), [12]Mountain Agricultural Grounds (MAG), [13]Negative ideal number (NI_n).

Table 7: Wind erosion intensity of TMUs

TMUs[1]	$\sum\left(a_{ij-D_{oj}}\right)^2$	WEM[2]	WEI[3]	Intensity Level	Class
(BMG)	4	2	0.09	Low	I
(MGPC)	19	4.35	0.20	Low	I
(BPPC)	83	9.11	0.42	Moderate	II
(BEP)	187	13.67	0.63	Intense	III
(EPPC)	179	13.37	0.61	Intense	III
(PAG)	223	14.93	0.68	Intense	III
(CGPC)	278	16.67	0.76	Very Intense	IV
(BCG)	281	16.76	0.76	Very Intense	IV
(BSD)	217	14.73	0.67	Intense	III
(SDPC)	287	16.94	0.78	Very Intense	IV
(IA)	125	11.18	0.51	Intense	III
(MAG)	16	4	0.18	Low	II

[1]Terrain Mapping Units
[2] Wind erosion Measure
[3]Wind erosion Intensity

about 67.8% of the region consisted of the lands outside of the wind erosion activity (Fig. 3).

Then, comparison charts of effective factors were provided by overlaying two layers of zonation map of wind erosion function areas and the mentioned thematic maps using geoprocessing.

Therefore based on the scope of variables fluctuation and their relationship with emergence of wind erosion facies in the region, the variables are divided into different levels and were weighed in scales 1 to 9 (Table 5)

Determining Value of Each Index in Each TMUs and Forming Data Matrix: By forming data matrix, value of each index in each TMUs was evaluated from the direction of influencing the process of erosion regarding to the table of indices scoring (Table 1) in scales 1 to 9. (Table 6)

Determining Ideal Value (Ni_j) from Data Matrix: In this stage, at the end of data matrix, the smallest observable number in each column was gained with the title of Ni_j ideal number because in this structure the less our scoring to each index in relation with each TMUs, will show less influence of that index in the process of wind erosion. Therefore the minimum numerical amount of indices in data matrix was gained under ideal title (Table 6).

Preparing the Matrix of Wind Erosion Intensity for Each TMUs: The square distance of each index was calculated from ideal number of the same index (NI_j) and entered in another 2D matrix titled "wind erosion intensity matrix" (Table 7). The small distance of each index from negative ideal number showed its small influence of this index on erosion process in those TMUs and vice versa.

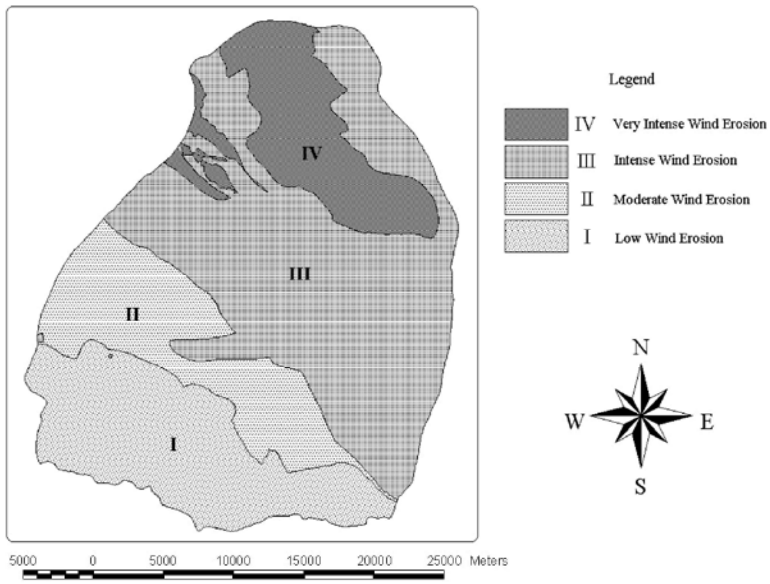

Fig. 4: Potential classification of wind erosion risk in Khezrabad region

Assessment of Wind Erosion Measure (WEM) in the TMUs: Then using Eq.2 total squares of deviations from ideal negative number was specified in each TMUs on the basis of indices, which is expressed under the title "TMUs Wind Erosion Measure (WEM)". (Table 7)

Calculating of the High Level of Wind Erosion (We_{max}): In order to determine the intensity of TMUs erosion intensity, determining the level, classification and preparing wind erosion classification map, high level of erosion in TMUs (WE_{max}) from relationship 3 was calculated equivalent to 21.83.

Determination of Wind Erosion Intensity in the TMUs: The wind erosion intensity in TMUs (WEI) was calculated from Eq. 4 based on the indices. Whereas according to this method, wind erosion intensity in TMUs is always between zero and one (0=WEI=1), therefore the more this concepts is closed to zero it indicates better status or less intensity of wind erosion in that TMUs and vice versa.

Based on the results from erosion intensity in TMUs (WEI), TMUs classification table as concerns erosion intensity was prepared (Table 7).

Preparing Wind Erosion Risk Classification Map: According to units classification table in term of wind erosion intensity (Table 4), each working unit located in one of the four class-of low, medium, high and very high. Finally on the TMUs map, final maps of wind erosion risk potential was prepared by combination of the units having same class using Arc View software (Fig. 4).

DISCUSSION

Evaluation of the wind erosion risk plays a very important role in natural resources management. In this research to prepare wind erosion risk zonation map, the modify taxonomy model (MNT) used. The results showed that in the classes of each layer, special class had the most talent to instability. In geomorphology layer, the most wind erosion function occurred in sandy sheets, dunes and agricultural land of epandage pediment less than 1200 meters height. In lithology layer: small grain, separated layers of traditional terraces and sand dunes, in soil layer: soil types epandage pediment with very low slope including small grain and deep loamy-clay soils with weak drainage status and high salinity, in vegetation cover layer: haloxylon sand dune units and without vegetation cover and in the land use layer: sand dunes with vegetation cover and range lands had the most sensitivity to the erosion.

To prepare the final layer of wind erosion risk zonation, the mentioned layers were combined in the form of modified numerical taxonomy model. The results showed that sandy dune units with plant coverage (SDPC), bare clay grounds (BCG) and clay grounds with plant coverage (CGPC), with the most quantitative value 0.76, 0.76 and 0.77 were prone to very intense wind erosion. In the meantime, the quantitative value of wind erosion risk for the entire region was estimated 0.52 which indicated intense potential of the region in occurrence of wind erosion. Generally based on final layer, 15% of the area of Khezr abad basin is prone to high risk (very intense) wind erosion and threatens the region with total wind erosion intensity classification of 70%.

These findings show that the studied area faces a lot of limitations, so in development plans it is necessary to pay attention to these limitations and it is recommended to run appropriate management system for natural resources such as water and soils. The authors believe that this model can be applied in other case studies.

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